

AD \_\_\_\_\_

Award Number: MIPR 1DCB8F1067

TITLE: Remote Echocardiography: Proof of Concept for Support  
of National Disasters, Combat and Humanitarian Mission

PRINCIPAL INVESTIGATOR: Sheri Yvonne Nottestad Boyd, M.D.  
Linda L. Huffer, M.D.  
Terry D. Bauch, M.D.  
James L. Furgerson, M.D.

CONTRACTING ORGANIZATION: Brooke Army Medical Center  
Fort Sam Houston, Texas 78234-6200

REPORT DATE: December 2002

TYPE OF REPORT: Final

PREPARED FOR: U.S. Army Medical Research and Materiel Command  
Fort Detrick, Maryland 21702-5012

DISTRIBUTION STATEMENT: Approved for Public Release;  
Distribution Unlimited

The views, opinions and/or findings contained in this report are those of the author(s) and should not be construed as an official Department of the Army position, policy or decision unless so designated by other documentation.

20040324 018

**REPORT DOCUMENTATION PAGE***Form Approved*  
**OMB No. 074-0188**

Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing this collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188), Washington, DC 20503

|                                                                                                                                                                            |                                                                 |                                                                |                                                                        |                                  |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------|----------------------------------------------------------------|------------------------------------------------------------------------|----------------------------------|
| <b>1. AGENCY USE ONLY</b><br>(Leave blank)                                                                                                                                 |                                                                 | <b>2. REPORT DATE</b><br>December 2002                         | <b>3. REPORT TYPE AND DATES COVERED</b><br>Final (31 Dec 00-31 Dec 02) |                                  |
| <b>4. TITLE AND SUBTITLE</b><br>Remote Echocardiography: Proof of Concept for Support of National Disasters, Combat and Humanitarian Mission                               |                                                                 |                                                                | <b>5. FUNDING NUMBERS</b><br>MIPR 1DCB8F1067                           |                                  |
| <b>6. AUTHOR(S)</b><br>Sheri Yvonne Nottestad Boyd, M.D., Linda L. Huffer, M.D., Terry D. Bauch, M.D., James L. Furgerson, M.D.                                            |                                                                 |                                                                |                                                                        |                                  |
| <b>7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)</b><br>Brooke Army Medical Center<br>Fort Sam Houston, Texas 78234-6200<br><br>E-Mail: SHERI.BOYD@CEN.AMEDD.ARMY.MIL |                                                                 |                                                                | <b>8. PERFORMING ORGANIZATION REPORT NUMBER</b>                        |                                  |
| <b>9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)</b><br>U.S. Army Medical Research and Materiel Command<br>Fort Detrick, Maryland 21702-5012                   |                                                                 |                                                                | <b>10. SPONSORING / MONITORING AGENCY REPORT NUMBER</b>                |                                  |
| <b>11. SUPPLEMENTARY NOTES</b>                                                                                                                                             |                                                                 |                                                                |                                                                        |                                  |
| <b>12a. DISTRIBUTION / AVAILABILITY STATEMENT</b><br>Approved for Public Release; Distribution Unlimited                                                                   |                                                                 |                                                                |                                                                        | <b>12b. DISTRIBUTION CODE</b>    |
| <b>13. ABSTRACT (Maximum 200 Words)</b><br><br>Attached.                                                                                                                   |                                                                 |                                                                |                                                                        |                                  |
| <b>14. SUBJECT TERMS</b><br>No subject terms provided.                                                                                                                     |                                                                 |                                                                |                                                                        | <b>15. NUMBER OF PAGES</b><br>15 |
|                                                                                                                                                                            |                                                                 |                                                                |                                                                        | <b>16. PRICE CODE</b>            |
| <b>17. SECURITY CLASSIFICATION OF REPORT</b><br>Unclassified                                                                                                               | <b>18. SECURITY CLASSIFICATION OF THIS PAGE</b><br>Unclassified | <b>19. SECURITY CLASSIFICATION OF ABSTRACT</b><br>Unclassified | <b>20. LIMITATION OF ABSTRACT</b><br>Unlimited                         |                                  |

**TABLE OF CONTENTS**

Cover

SF 298

Table of Contents

Abstract

Body

Key Research Accomplishments

Reportable Outcomes

Conclusions

Appendix A: Technical Summary

Appendix B: Funded Personnel and Participants

Appendix C: Supporting Documentation

Appendix D: Presentations, Posters, Publications

**ABSTRACT**

**ABSTRACT**

---

Echocardiography is an essential tool in the evaluation of patients with cardiac emergencies and chest trauma. The objective of our study was to establish the feasibility and diagnostic accuracy of a portable satellite transmission system in the assessment of cardiac emergencies for the real-time support of mass casualty and humanitarian relief efforts. Twelve patients with cardiac structural disease identified by conventional in-hospital transthoracic echocardiography (TTE) were transported to a remote portable field hospital where TTE was performed with a hand-held echocardiographic device. Images were then relayed by a commercial VSAT satellite to a level 3 trauma center where they were interpreted in real-time by a cardiologist. Remote VSAT studies were recorded at the field hospital prior to satellite transmission and again upon download at the receiving facility. The remotely acquired studies before and after satellite transmission were compared to each other and subsequently compared with conventional hospital TTE for technical quality and diagnostic accuracy using a blinded single reader side-by-side comparison. Excellent agreement was found between the recorded field-site and satellite-transmitted images with an overall average of 95% concordance. When the field data acquired with the handheld device and satellite transmission was compared to the conventional in-hospital echocardiography, a high degree of agreement was demonstrated in overall technical quality (83%) and assessments of left ventricular ejection fraction (100%), pericardial effusion (100%), and left ventricular size (92%). This study demonstrates the feasibility and diagnostic accuracy of remote, real-time echocardiography using VSAT satellite transmission for mass casualty triage or humanitarian relief efforts.

---

## **BODY**

Cardiac injury resulting from chest trauma is an important source of morbidity and mortality, and accounts for 20-25% of all traumatic deaths (1). Such injury may occur via blunt or penetrating injury. Blunt trauma may result in myocardial contusion or rupture, acute valvular incompetence, or ventricular aneurysm (2). The most common of these injuries is myocardial contusion which may be detected on echocardiography as wall motion abnormalities, wall thickness changes, or ventricular dilatation. The most common sequelae of penetrating cardiac injury is pericardial effusion, with or without tamponade, which is found in 57-69% of patients who sustain penetrating cardiac injury (3). Despite the high prevalence of tamponade in cardiac trauma, the classic findings of arterial hypotension, elevated central venous pressure, and muffled heart sounds (Beck's triad) are seen in only a small number of patients (3). Thus, physical exam and clinical findings alone may be misleading and unreliable in the evaluation of patients with cardiac trauma.

Echocardiography provides the capability to quickly diagnose a wide variety of cardiac injuries and can provide critical data for triage officers and trauma surgeons. It can be performed rapidly and non-invasively at the patient's side and can detect evidence of serious cardiac pathology prior to the development of clinical signs and symptoms. Previously published studies have demonstrated that screening 2-D echocardiography in the emergency department improves survival and neurologic outcome when used in the acute evaluation of victims of penetrating cardiac injury (4). However, in the remote trauma environment, as might be experienced by medical units in a mass casualty or humanitarian mission, the availability of expert echocardiographic interpretation is limited.

Telemedicine technology is perhaps best used when it provides the vital link between the remote patient in need of expert evaluation and a highly trained specialist who would not normally be available in a setting of limited resources or an austere health care environment. The United States Army has been engaged in the development and application of telemedicine in disaster relief and combat settings since the 1980's (5). Telecardiology, specifically tele-echocardiography, is the fastest growing field in telemedicine (6). Tele-echocardiography has previously been shown to be a valuable and cost-effective triage tool in the neonatal and pediatric settings (7).

Transmission of echocardiographic studies via satellite with rapid interpretation by a cardiologist would allow this imaging modality to be utilized in the remote, deployed environment, thereby improving diagnosis and triage. In addition, hand-held echocardiographic devices have been introduced that are well-suited for such an environment because of their small size, portability, and reduced cost. Our objective, therefore, was to establish the feasibility and diagnostic accuracy of a hand-held portable tele-echocardiographic system using real time satellite transmission in a simulated mass casualty setting.

## **METHODS**

The study participants included 12 individuals with known structural cardiac disease. Subjects were recruited by screening the computerized database of echocardiographic studies at a tertiary care military medical center to identify individuals with known cardiac disease as demonstrated by conventional echocardiography. The study group included 8 women and 4 men with a mean age of  $61 \pm 14$  years. After obtaining informed consent, the subjects were transported to a local training facility where a military combat-support field hospital was erected. Portable, hand-held echocardiograms were performed on each subject using a 2 mHz transducer and a

Sonosite 180 (Sonosite, Bothel, WA). The video output from the portable echocardiographic system was fed into a wireless 250mW microwave transmitter worn in a custom-designed tactical vest and also to a digital video recorder. The tactical vest allowed for ambulatory imaging of patients throughout the hospital tent. The video signal was then transmitted at distances up to 1,500 feet during imaging to a high gain sector antenna positioned just outside the field hospital. From the antenna, the signal was converted via an asynchronous RS-232 serial protocol and passed to the data port of a very small aperture terminal (VSAT) satellite uplink. Upon downlink, communication was then rapidly established with a tertiary referral site for real-time review by a cardiologist (Figure 1). The tactical vest allowed for real-time verbal and video communication between the sonographer and the reviewing cardiologist.

The recorded field-site images and VSAT transmitted images were then assessed for technical quality in a single reader, side-by side comparison. Diagnostic accuracy was also assessed by comparing the two sets of recorded images in a randomized, blinded fashion with conventional echocardiography performed on the Sequoia C256 (Acuson, Bothell, WA) in a fixed facility within 4 months of field data acquisition. The echocardiographic features graded included overall technical quality, left ventricular ejection fraction and size, presence of a pericardial effusion, regional wall motion abnormalities, valvular stenosis, and moderate to severe valvular regurgitant lesions. These features include the abnormalities that would be demonstrated by echocardiography in cardiac trauma. They also include important diagnoses that may significantly impact patients' hemodynamic profiles such as valvular stenosis and regurgitation. The data were then analyzed using a Cohen's kappa statistic for agreement.

**KEY RESEARCH ACCOMPLISHMENTS**

- 1) Successfully deployed VSAT in CSH field environment with connectivity to level I Trauma Center
- 2) Successfully imaged patients with underlying cardiac conditions in CSH environment with accurate interpretation of images sent via Telemedicine.



## **REPORTABLE OUTCOMES**

### **RESULTS**

The recorded field-site images and transmitted images were assessed for technical quality in a single reader, side-by side comparison, blinded to the location where images were recorded. We found excellent agreement with an overall average of 95% concordance between the two sets of images. Specifically, complete agreement was seen in the ability to assess left ventricular function and the presence of a pericardial effusion. With respect to the remaining variables, complete agreement between the two sets of images was detected in 10 of the 12 studies ( Figure 2). This data demonstrates no significant loss in image quality or interpretation with VSAT and wireless vest transmission.

Diagnostic accuracy was also assessed by comparing the two sets of recorded field-site images in a randomized, blinded fashion with in-hospital conventional echocardiography (Figure 3). Agreement was demonstrated in overall technical quality (TQ) and assessments of left ventricular ejection fraction (EF), pericardial effusion (PE), and left ventricular size. Specifically, good agreement was noted in TQ ( 83%), EF (100%), PE (100%),and LV size (92%) between hospital TTE and VSAT transmitted images. Poor agreement, however, was noted in the assessment of specific LV wall motion abnormalities (WMAs) and mild valvular stenotic and regurgitant lesions indicating reduced accuracy with comparison to the gold standard of conventional TTE.

## CONCLUSIONS

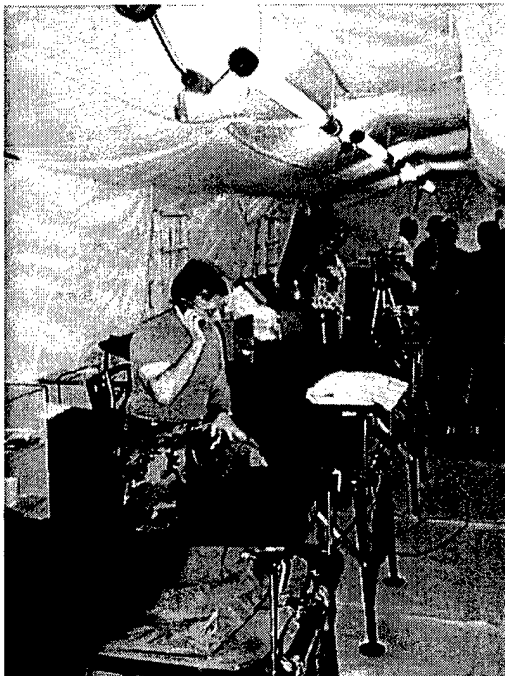
### **DISCUSSION**

This study demonstrates the feasibility of VSAT satellite transmission and real-time interpretation of portable echocardiography in a mass casualty triage or humanitarian relief effort. Diagnostic-quality echocardiography is achievable for the detection of important features of cardiac emergencies including the presence of a pericardial effusion, left ventricular enlargement, and systolic dysfunction. However, the data did demonstrate poor agreement in the evaluation of valvular lesions and specific wall motion abnormalities. Small, hand-carried echocardiographic devices have been recently introduced with favorable early reports in the outpatient setting, on inpatient wards, and in a small cohort of ICU patients (8-12). Some of these reports have shown good correlation between hand-carried devices and conventional echocardiography for the evaluation of wall motion and valvular regurgitation (11). Our results support the findings of Goodkin et al who reported a lower sensitivity in the evaluation of valvular regurgitation when the SonoSite 180 was used to evaluate a cohort of critical care patients (12). The authors hypothesized that this shortcoming was secondary to the absence of true color flow and spectral Doppler systems and M-mode capabilities. The remotely acquired handheld echocardiograms performed in the current study missed one case of moderate mitral regurgitation and one case of moderate tricuspid regurgitation. Larger studies will be required to further define the significance of this limitation.

We believe that portable echocardiographic technology can serve as a cardiology-force multiplier allowing for rapid diagnosis and triage even in remote settings where advanced diagnostic modalities have not previously been available. In addition, the capability for real-time interpretation and communication between the sonographer in the remote environment and the

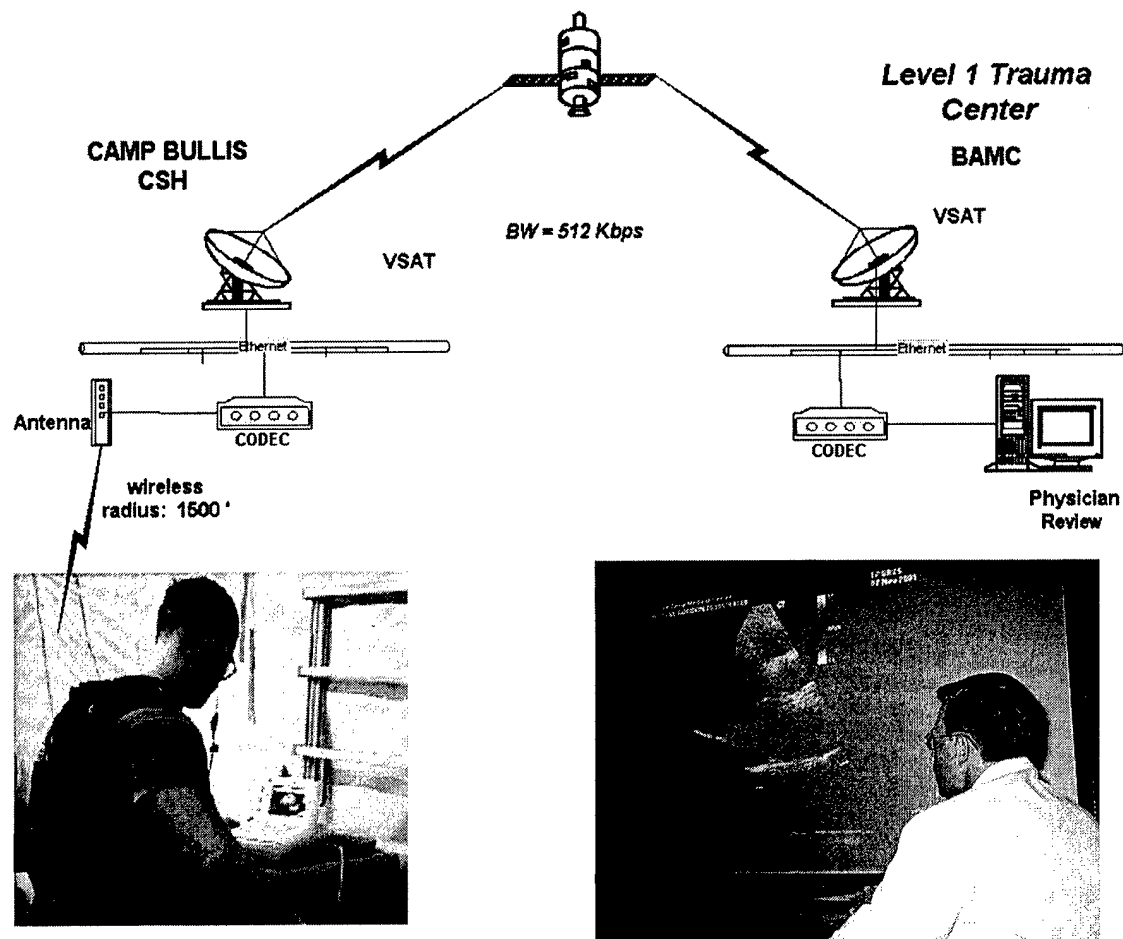
cardiologist allows for immediate feedback to guide data collection. Further evaluation is needed to determine if technical improvements in the image quality of portable ultrasound imaging systems or satellite transmission bandwidth will improve the diagnostic quality of images for remote assessment of wall motion abnormalities and mild valvular lesions.

The authors gratefully acknowledge the support of Mr. James Bulgrin, Dr. Bernard Rubal, Ms. Vicki Hamlin, Mr. Tommy Morris, Mrs. Vernadette LaManna, and Mr. Frank LaManna for their support in this project.

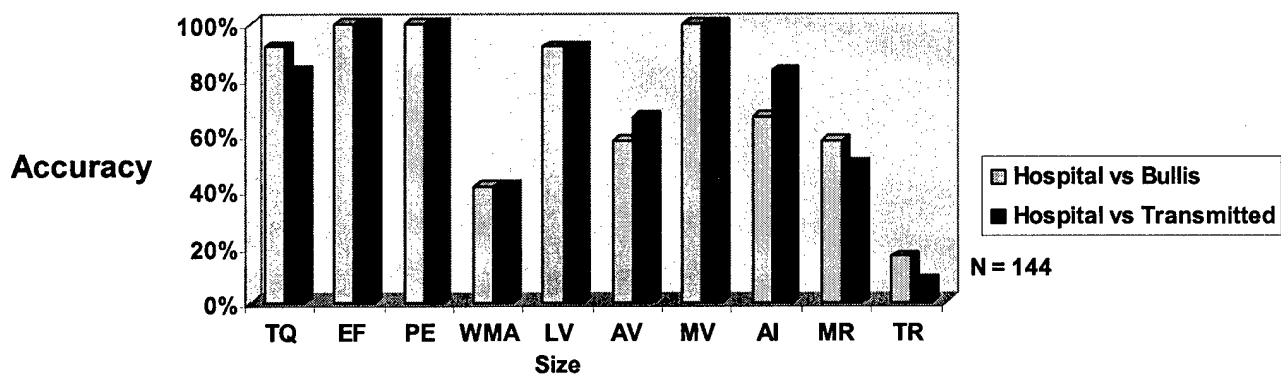


**Hospital Ward**

## APPENDIX A: TECHNICAL SUMMARY



### Overall Agreement with Hospital Echo



**APPENDIX B: FUNDED PERSONNEL AND PARTICIPANTS**

Mr. James Bulgrin

Dr. Bernard Rubal

Ms. Vicki Hamlin

Mr. Tommy Morris

Mrs. Vernadette LaManna and Mr. Frank LaManna.

LTC Sheri Boyd

LTC Terry Bauch

MAJ James Furgerson

CPT Linda Huffer

Mr Russell Woods

Mr Larry Markins

## **APPENDIX C: SUPPORTING DOCUMENTATION**

### **REFERENCES**

1. Rutherford, RB, Ballinger WF, Rutherford RB, Zuidema GD, eds. The Management of Trauma. 2nd ed. Philadelphia, PA: WB Saunders Co;1973:333.
2. Chan, D. Echocardiography in thoracic trauma. Emerg Med Clin NA 1998;16:191-207.
3. Freshman SP, Wisner DH, Weber CJ. 2-D echocardiography: Emergent use in the evaluation of penetrating precordial trauma. J. Trauma 1991;31:902-6.
4. Plummer D, et al. Emergency department echocardiography improves outcome in penetrating cardiac injury. Ann Emerg Med. 1992;21:709-12.
5. Garshnek V, Burkle F. Applications of telemedicine and telecommunications to disaster medicine: Historical perspectives. JAMIA 1999;6:26-37.
6. Sable, C. Telecardiology: Potential impact on acute care. Crit Care Med. 2001; 29:159-65.
7. Finley JP, Sharratt GP, et al. Pediatric echocardiography by telemedicine-ten years' experience. Circulation 1997;96:S510-1.
8. Bruce CJ, Zummach PL, et al. Personal ultrasound imager: Utility in the cardiology outpatient setting (abstr). Circulation 2000;102:102:II364.
9. Pandian NG, Ramasamy S, et al. Ultrasound stethoscope as an extension of clinical examination with a hand-held miniaturized echocardiography instrument (abstr). J Am Soc Echocardiogr 200;13:486.
10. Firstenberg MS, Cardon L, et al. Initial clinical experience with an ultra-portable echocardiograph for the rapid diagnosis and evaluation of critically ill patients (abstr.) J Am Soc Echocardiogr 200;13:486.

**APPENDIX D: PRESENTATIONS, POSTERS, PUBLICATIONS**

**Submitted for publication – Journal of the American Society of Echocardiography  
Awaiting approval of revisions**

**Presented at the American Society of Echocardiography, Orlando FL, June 2002**

**Abstract published:**

**Huffer, LL, Bauch, TD, Boyd, SYN, Bulgrin, JR. Remote Echocardiography Using Very Small Aperture Terminal (VSAT) Satellite Transmission for Real-Time Support of Mass Casualty and Humanitarian Relief Efforts. JASE;2002:493.**